Secondary Compounds in Foods Selected by Free-Ranging Primates on St. Catherines Island, GA

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ABSTRACT

The foraging behavior of two groups of free-ranging primates, ring-tailed lemurs *(Lemur catta)* and lion-tailed macaques *(Macaca silenus),* residing on St. Catherines Island Wildlife Center, Georgia was observed seasonally at quarterly intervals for one year. Each group (N=13, N=9, respectively) had unlimited access to native flora and fauna in addition to a daily provisional diet. Representative samples of non-provisioned items eaten by both species were collected during the sampling interval and analyzed for secondary compounds in order to assess their impact on food choice. It was assumed that the free-range intake would represent preferred food since known nutritional needs can be met through the provisioned diet. Therefore, it was hypothesized that items high in potential toxins and digestion inhibitors (i.e., plant secondary compounds) would be avoided. We were also interested in any interspecific differences with regard to food choice and secondary compounds. Results showed that there was no statistically significant overlap in the types of foods selected by the two species. Despite differences in food choice, however, subsequent analyses did not reveal consistent patterns in phytochemical content between the two primate species' diets. Moreover, both species consumed foods with a wide ranging concentration of total phenolics, hydrolyzable and condensed tannins.

Key Words: secondary compounds, ring tailed lemurs, lion tailed macaques, food selection

INTRODUCTION

The foraging behavior of two groups of free-ranging primates, ring-tailed lemurs *(Lemur catta)* and lion-tailed macaques *(Macaca silenus),* residing on St. Catherines Island Wildlife Survival Center, Georgia was observed seasonally at quarterly intervals for one year .St. Catherines Island is a barrier island off the coast of Georgia which covers approximately 57.8 km2 and is characterized by several distinct habitats: mixed deciduous and evergreen forests, palmetto, savanna, and both fresh and saltwater marshes (Thomas, 1988). The ring-tailed lemurs were first released on St. Catherines Island in 1984 and now consist of three social groups. They, along with black-and-white ruffed lemurs *(Varecia variegata variegata),* occupy the northern part of the island. The lion-tailed macaques were introduced onto the island in 1990, and occupy

an area in the southern part. Both the ring-tailed lemurs (N=13) and the lion-tailed macaques (N=9) have unlimited access to native flora and fauna in addition to daily provisioned diets (consisting of a commercial primate biscuit and a variety of produce) that are known to support growth and reproduction of captive groups. Thus, plant items consumed by free-ranging primates were considered to be preferentially selected from available forages. This study is part of a larger project to evaluate and compare the nutrient composition of diets consumed by free-ranging primate species on St. Catherines Island.

MATERIALS AND METHODS

Ring-tailed lemurs were from Group #2, consisting of 13 animals (7 = male, 6 = female) ranging in age from 1 month to 9 years. The macaque group consisted of 9 animals (5 = male, 4 = female) ranging in age from 10 months to 24 years.

The observational sampling of foraging behavior and the laboratory analysis of plants followed standardized methodologies as reported by studies of primate foraging (see Smuts et al., 1987 and Yeager et al., 1997). The methods of observational sampling for this study consisted of 3 two-day follows per species during one month for four months (seasonally) during the year. A 2-day follow consisted of two consecutive days of sampling during the A.M. and P .M. periods on one species, and the three sets of follows for each species were conducted during the same designated month for comparative purposes. In this study we used two sampling periods to observe foraging behavior when the animals would most likely be actively foraging: four-hour blocks from 06:30 to 10:30 and from 16:00 to 20:00. The sample period start times varied according to seasonal changes in daylight hours.

The sampling period began and ended with a scan sample of the group. Scan samples were taken every 10 minutes during the sample period. During the scans we recorded the behavior of
the animal (foraging or non-foraging). If foraging, we recorded the plant species, plant part being eaten, and foraging height.

In addition to the scan sampling, continuous focal animal samples were collected on each animal in the group for 20 minute durations. The order of animals sampled was rotated daily so that each animal was sampled during each time of the sample period. During the focal samplings, we recorded when the focal animal was observed foraging, the time, the plant species, plant part, foraging height, and any other ad libitum notes. When the focal animal stopped foraging and began a new behavior, the stop time was recorded in order to record the duration of foraging bouts.

Based on feeding observations, representative samples were manually collected from 3 to 5 individual plants per species. We attempted to obtain 50 to l00 g (wet weight) of material for subsequent chemical analyses. Samples were weighed to 0.1 g, dried in a forced-draft oven at <60C until constant weight to determine moisture content, ground through a 2 mm screen in a Wiley laboratory mill, and kept at room temperature until analysis.

Phenolic extractions were prepared using 50% methanol (Bate-Smith, 1977, 1981 ; Hagerman and Butler, 1991). Chemical procedures followed Shure and Wilson (1993) and Dudt and Shure (1994). The Folin-Denis technique was used to assay for total phenolics (TP) (Swain and Hi11is, 1959). Hydrolyzable tannins (HT) (ellagitannins) were measured under an N2 environment using an acetic acid-sodium nitrate procedure (Bate-Smith, 1972, 1977). Condensec tannins (CT) were estimated as proanthocyanidins using a butanol-HCl technique (Bate-Smith,

1975,1981). Tannic acid and quebracho tannin were used as standards for total phenolics and condensed tannins, respectively. Total phenolics are expressed as percent dry weight tannic acid equivalents (%TAE), hydrolyzable tannins as mg per gram dry weight of hexahydroxydiphenol-glucose equivalents (mg/g HHDP), and condensed tannins as percent dry weight quebracho tannin equivalents (%QTE).

RESULTS

The behavioral data are based on 360 hours of observation collected in quarterly periods over the course of one year (90 hours per quarter). Continuous animal focal sampling consisted (144 hours of observation for the lion-tailed macaque group (36 hours per quarter), while the ring-tailed lemur group totaled 208 hours of observation time (52 hours per quarter). Equal numbers of scan samples were taken on each of the study groups and totaled 1104 samples (276 scans per quarter per study group).

A total of 30 species of plants were identified as eaten over the course of this study, along with unknown species of grass and mushrooms (Table 1). Leaves, stems, twigs, fruits, buds, and seeds were sampled separately as consumed. Only nine plant species were consumed by both primate groups. Three species (sugarberry leaves, chinaberry berries, and cabbage palm berries) were consumed over 3 sampling periods by ring-tailed lemurs. Three different species (live oak, Spanish moss, and grass) were eaten over 3 sampling periods by the lion-tailed macaques, with live oak leaves consumed throughout the year.

Despite differences in food choice, subsequent statistical analyses (SSP for Macintosh) did not reveal consistent patterns in phytochemical content between the two primate species' diets (MANOVA, Wilks lambda = .98385). Moreover, both species consumed foods with a wide ranging concentration of total phenolics, hydrolyzable and condensed tannins (Table 2). Leaves and fruits generally had the highest concentrations of total phenolics and condensed tannins, although acorns had very high levels of total phenolics and hydrolyzable tannins (Table 3).

DISCUSSION

Plant secondary compounds have long been thought to have a deleterious effect on herbivorous animals, and therefore should be avoided in their diet. Evidence is mounting, however, that sheds new light on this theory (see Palo, 1984; Martin et al., 1987; Mole and Waterman, 1987; Mowry et al., 1996) and actually suggests that some plant metabolites (e.g., phenolics) may be a necessary component of a mammalian herbivore's diet. Spelman et al. (1989) found that captive lemurs were extremely susceptible to excess iron deposition (hemosiderosis) it the duodenum, liver, and spleen, and they attributed this disease to a diet high in iron and ascorbic acid, and low in tannins. The tannins consumed by wild lemurs (including those on St. Catherines Island), as well as other herbivorous mammals, may help to control iron metabolism (Roy and Mukherjee, 1979).

Our current data do not yet provide a complete picture of the feeding ecology of the St. Catherines Island primates. We can only draw limited conclusions without knowing, for example, ranked preferences of dietary items or amounts consumed of each plant species and item. However, the data do show that both primate species are sampling a wide array of items to supplement their provisioned diet. It is important to note that items high in secondary compound

are not being avoided. With further studies, we hope to determine the degree of preference for such items and their role in the *Lemur catta* and *Macaca silenus* diet.

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Table 1. Plants eaten by free-ranging primates on St. Catherines Island,GA, 1996.

Species	Common name	Plant Part	Eaten by Ring-tailed lemur*	Eaten by Lion-tailed macaque*	Eaten by Ruffed lemur*
Arundinaria gigantea	Giant cane	Leaves	N	M, A	
		Stem, dead shoot	A	A	
Bumelia tenax	Buckthorn	Leaves	A		
		Berries	A		
Carya ovalis	Small pignut	Leaves	A		
		Insect galls	M		
Celtis laevigata	Sugarberry	Leaves	M, A, N		
		Twig		N	
Celtis occidentalis georgiana	Hackberry	Leaves	A		
		Buds	F		
		Insect galls	A		
Chenopodium ambrosiodes	Mexican tea	Leaves	M		
Cornus florida	Flowering dogwood	Buds	N		
Diospyros virginiana	Persimmon	Fruit	A, N		
Ilex opaca	American holly	Leaves		M	
		Berries	F	N	
Ilex vomitoria	Yaupon	Leaves	F		
		Berries	N		
Juniperus silicicild	Red cedar	Bark	A, N		
		Berries	A	A	
Magnolia grandiflora	Southern magnolia	Leaves	M		
		Flower buds	M	M	
Melia azedarach	Chinaberry	Leaves	A		
		Twig	A		
		Berries	M, A, N		
Myrica cerifera	Southern bayberry/wax myrtle	Leaves	M, F	A	A
Parthenocissus quinquefolia	Virginia creeper	Leaves	M	A	
		Vine		A	
Persea borbonia	Red bay	Leaves	A, N	M	
		New growth		M	
		Fruit	A, N		
Phoradendron flavescens	Mistletoe	Berries	F		
Pinus taeda	Loblolly pine	Branches, bark	A	A, F	
		Seeds		N	
Polypodium polyploides	Resurrection fern	Whole		A	
Prunus caroliniana	Carolina cherry laurel	Fruit	F		
		Flower buds	F		
Quercus virginiana	Live oak	Leaves	A, F	M, A, N, F	
		Buds	F		
		Bark, twigs, wood	M	M, A, F	
		Acorn	N	A, N, F	
Rubus betuifolius	Blackberry	Berries	M	M	
Sabel palmetto	Cabbage palm	Berries	A, N, F	A	
Smilax laurifolia		Leaves		A	

		Vine	F		
Solanum nigrum	Common nightshade	Berries	N		
Tillandsia usneoides	Spanish moss	Leaves	A, F	M, A, N	
Vaccinium arboreum	Sparkleberry	Leaves	A		
		Berries	F		F
Vitis cinerea	Nut muscadine	Fruit	A	A	
Vitis rotundifolia	Muscadine grape	Leaves	M	M, A	A
		Bark		A	
		Fruit	A, N	A	A
		Vine		N	
Zanthoxylum clava-herculis	Hercules' club	Flower buds	M		
		Leaves	M		
	Unknown grass sp.	Leaves	M	M, A, F	
	Mushrooms (unknown spp.)	Whole	F	A	

Table 2. Range of concentration of plant secondary compounds consumed by primates on St.Cathrines Island, GA, 1996. (TP= total phenolics expressed as precent dry weight tannic acid equivalents, HT=hyroxydiphenoglucose equivalents, CT= condensed tannins expressed as precent dry weight quebracho tannin equivalents)

Species	**TP**	**HT**	**CT**
Lemur catta	0 – 9.3	0.2 – 41.8	0.2 - 72.1
Macaca silenus	0 – 10.1	0.2 – 22.8	0.1 - 92.8

Table 3. Mean secondary compound levels for plant parts eaten by primates on St. Catherines Island, GA, 1996. (TP= total phenolics expressed as precent dry weight tannic acid equivalents, HT=hyroxydiphenoglucose equivalents, CT= condensed tannins expressed as precent dry weight quebracho tannin equivalents)

Plant Part	**TP**	**HT**	**CT**
Leaves (N=35)	1.75	5.88	20.77
Fruits (N=22)	0.74	5.18	17.55
Woody Tissue (N=10)	0.136	1.64	1.13
Acrons (N=3)	4.96	26.24	5.04
Other (N=8) *	0.25	1.96	6.48

*Includes Spanish Moss, mushrooms, grass, insect galls